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Survey of Currently Available Non-Incineration PCB Destruction Technologies

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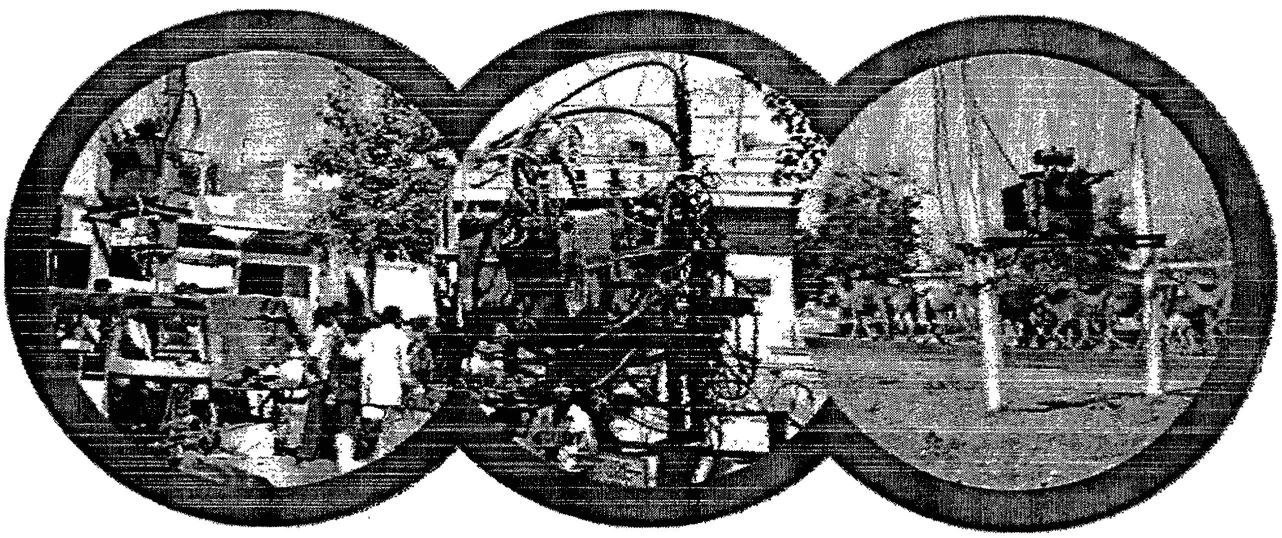
August 2000



Prepared by UNEP Chemicals

IOMC INTER-ORGANIZATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS

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UNEP CHEMICALS

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Preface

This publication is UNEP's third on the difficult issues posed in managing of polychlorinated biphenyls (PCBs). UNEP's first publication on PCBs was the "Inventory of Worldwide PCB Destruction Capacity" in 1998, followed by "Guidelines For the Identification of Materials Containing PCBs" in 1999. The "Survey of Currently Available Non-Incineration PCB Destruction Technologies," continues the series.

PCBs are chemical substances which are persistent, bioaccumulate, and pose a risk of causing adverse effects to human health and the environment. They can be transported long distances, and have been detected in the furthest corners of the globe, including places far from where they were manufactured or used. While manufacture of PCBs has reportedly ceased, the potential or actual release of PCBs into the environment has not, since significant quantities of existing PCBs continue in use or in storage.

The likely extended period of these continuing uses, and the persistence of PCBs once released into the environment together mean that PCBs could pose a threat for decades to come. Accordingly, UNEP's Governing Council included PCBs among the 12 persistent organic pollutants (POPs) identified for international action.

The Council, at its nineteenth session in February 1997 concluded that international action, including a global legally binding instrument, is required to reduce the risks to human health and the environment arising from the release of the 12 POPs (PCBs, dioxins and furans, aldrin, dieldrin, DDT, endrin, chlordane, hexachlorobenzene, mirex, toxaphene, and heptachlor). It requested UNEP to prepare for and convene by early 1998 an intergovernmental negotiating committee (INC), with a mandate to prepare an international legally binding instrument for implementing international action, beginning with the 12 POPs. The Council also requested UNEP to initiate a number of immediate actions, including intensifying POPs information exchange; improving the availability of information on alternatives to POPs; developing an inventory of PCB destruction capacities and assisting countries in identifying PCBs; and assisting countries in identifying dioxin and furan sources.

To promote the development and sharing of information on the twelve specified POPs, UNEP has established a network of government designated focal points for exchanging technical information and obtaining expertise for the development of various products. Information on available PCB-destruction facilities from these focal points and other sources, notably from the Secretariat of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, was incorporated into the UNEP "Inventory of Worldwide Capacity to Destroy PCBs" mentioned above.

This companion publication, "Survey of Currently Available Non-Incineration PCB Destruction Technologies," responds to requests for information on, and to continuing interest in alternatives to incineration. The Survey identifies more than 20 vendors who represent that they can treat and destroy PCB oils, transformers, or capacitors, using chemical or physical processes. UNEP does not, of course, endorse, approve, or certify vendors or processes. The Survey's purpose is simply to further respond to the UNEP Governing Council's request that UNEP develop and publish information to assist countries in ensuring the environmentally sound management of PCBs. The Survey thus provides PCB holders with information on available alternatives to incineration that they may wish to pursue further.

UNEP thanks donors, especially Switzerland's Agency for the Environment, Forests, and Landscape (BUWAL) and the USA, for their contributions, through which the production of this document was made possible. Both this publication and its companion publications on PCBs (see above) should be considered dynamic and will be updated as new information becomes available. Accordingly, UNEP Chemicals welcomes information or suggestions that could be incorporated into future revisions of the documents.

Klaus Töpfer
Executive Director
United Nations Environment Programme

I. SURVEY APPROACH AND OVERVIEW

1. INTRODUCTION

UNEP, in collaboration with the Secretariat of the Basel Convention, has recently published a volume entitled *Inventory of Worldwide PCB Destruction Capacity* (1998). The Inventory attempted to present as complete as possible a list of installations set up across the world, and ready to receive and to treat PCB-contaminated materials. It identified about 50 such facilities existing in about 50 countries in Europe, America, Asia (including Australia) and Africa, many of them incinerators.

The decision maker's ultimate choice of technologies will depend upon a number of factors, and may indeed result in a decision to use incineration. The objective of the present volume, however, is to explain in more detail what practical technologies other than incineration exist for rendering harmless a range of products which are contaminated with PCBs.

These products are:

- electrical transformers,
- capacitors,
- transformer oils, and
- waste oils.

This means that other commonly found materials which may be polluted with PCBs (soils, building materials, waste clothing, other debris, etc.), are not covered by this handbook. Such materials may be decontaminated by treatment with a solvent, however, and the resulting solvent + PCBs may then be processed by some of the methods covered here.

2. OBJECTIVES AND METHODOLOGY

The information presented in this volume has been obtained by surveying a range of companies who were reported to have developed technologies for the destruction of PCBs. These companies were identified largely through the data included in the *Inventory of Worldwide PCB Destruction Capacity*, cited above.

The destruction of PCBs is a subject on which much research has been carried out, and is still being carried out. This is a reflection on the present situation with regard to PCB decontamination. Industrialised countries, in particular OECD countries, have based their PCB elimination programmes on the fact that they can use the fairly large number of high temperature incineration facilities already existing.

This situation has arguably meant that there has been a brake to the development of alternative, non-incinerative decontamination technologies, with the result that such alternatives therefore occupy only a relatively small place in terms of tonnages destroyed in the developed countries. The further consequence of this is that developing countries which do not have incineration facilities, and which are unlikely to be able to build such facilities because of the costs and also because of community resistance to the building of new incineration facilities, are facing problems in identifying appropriate technologies to deal with the elimination of PCBs and PCB-containing materials in their countries.

There exist nevertheless many PCB elimination technologies which are already being applied to the elimination of a range of PCBs and PCB-containing materials, in particular transformers, capacitors, and oils. It is the objective of this handbook to present those alternative technologies which have already been developed and which are available for use on an industrial scale. These technologies have the particular advantage of being applicable on a smaller scale than is incineration, and are of course, when correctly applied, able to comply with the environmental management regulations of the countries in which they have been licensed.

3. THE QUESTIONNAIRE

The methodology used for this handbook has been to draw up a questionnaire which was sent out to those companies known to operate non-incinerative PCB destruction technologies, as identified in the UNEP publication *Inventory of Worldwide PCB Destruction Capacity* and other sources. The questionnaire used for this investigation is appended as Annex 1.

The questionnaire was addressed to companies believed to have developed and/or to be exploiting technologies which can be applied to the treatment of transformers, capacitors, and oils, with a view to eliminating completely the PCBs they contain. The questionnaire was sent to about 50 companies - essentially in Europe and the USA. Half this number of replies was received. Also, the UNEP Focal Points in many countries were consulted to ensure that the information received represented was a fair reflection of the situation in their countries concerning PCB destruction activities.

The information requested covered all the basic characteristics of the process:

- its effective present use for PCB destruction (industrial status);
- the basic principle of the technology;
- applicability;
- details of the process;
- capacities of existing installations;
- process costs;
- environmental considerations (production of gaseous, liquid or solid effluents); and
- current availability to interested companies and organisations who may wish to apply the technology.

These technologies should preferably be applicable to the smaller quantities of PCB wastes often found in developing countries. Many countries with acute PCB problems do not necessarily have large amounts of wastes, and consequently a compact, even mobile destruction unit may be sufficient to address, and solve, their PCB contamination problems.

4. THE SCOPE OF THE SURVEY

Incineration continues to be the method of choice for destroying PCBs in Europe and America. As mentioned earlier, this survey does not cover incineration, in part because it is such a widely used and well known technology for PCB elimination. In addition, establishment of an in-country incineration capability is unlikely to be viable for regions of the world where the volume of PCB wastes to be destroyed is less than the relatively large volumes needed to attain the break-even point for the economic operation of such plants.

The report also does not address the treatment or disposal of contaminated soil or other media. In part, this is because the technologies which can be used to decontaminate soils are different from those which can be applied to transformers, capacitors, and oils. Also, since types of soils can be very different, a variety of different approaches must be considered for soil cleanup. The nature of the problem means that soil decontamination should more appropriately be addressed in a separate report.

5. OVERVIEW OF THE OCCURRENCE OF PCBs

For detailed information about the properties and uses of PCBs, the reader is referred to a previous UNEP publication which appeared in 1999, *Guidelines for the Identification of PCBs and Materials Containing PCBs*. That publication presents a good overview of the history of PCB manufacture and of the many uses to which the chemical has been put. It also details the products in which PCBs have been used, and the manner in which the products can be recognised.

It is useful in the present context, however, to give a summary of the main categories of use of PCBs, and to explain which ones are covered here from the point of view of the destruction of PCBs.

The uses of PCBs can be classified into three categories:

- closed applications;
- partially closed applications, and
- open applications.

This classification is useful since it indicates the likelihood with which the PCB can be released, intentionally or unintentionally, thereby leading to a PCB contamination problem. The present volume covers materials which are included in the closed or partially closed application categories.

5.1 Closed applications

As the name implies, closed uses are those in which the PCBs are enclosed, and cannot escape during normal use. The main examples are transformers and capacitors, which are sealed pieces of electrical equipment. Apart from accidents (fire, mechanical damage, etc.) the PCB will remain in a safe environment -- at least until the end of the working life of the equipment in which it is enclosed.

5.2 Partially closed applications

In these, the PCB-containing oil is employed as a fluid which is called upon to move during use, for example as a heat transfer fluid, as a hydraulic fluid, in pumps, or in switches. This movement implies the presence of joints and seals in the equipment, offering the possibility that these items of equipment can release small amounts of fluid during normal operation.

5.3 Open applications

In open applications, the PCBs are generally incorporated into a formulation, usually in small or very small amounts. Such products can be lubricants, adhesives, paints, inks, etc. The PCBs become then very dispersed according to each application, and it is virtually impossible to consider destroying them. The solution to this problem is instead found further upstream, i.e., to ban the incorporation of PCBs in such products; this of course is already done in most countries, although many products manufactured earlier may still be in use.

This volume describes technologies which can be applied the destruction of PCBs which are covered by the first two categories of application. In particular, these PCB-contaminated materials are:

- transformers,
- capacitors,
- transformer oils, and
- waste oils

It also deals with technologies allowing the above PCB-contaminated materials to be not only decontaminated, and also recycled in certain cases.

6. OVERVIEW OF CURRENT PCB DESTRUCTION TECHNOLOGIES

The great majority of PCB wastes being destroyed today are being destroyed by incineration. The reason for this is that high temperature incineration is a technology which is well developed and readily available in many industrialised countries. Most of these plants are to found in Europe and America. They have not necessarily all been built for the purpose of destroying PCBs and halogenated compounds, as some have been built for the in-house wastes of chemical companies. It should be noted here that some industrialised countries no longer permit such incinerators, the most prominent examples being Japan (PCBs) and Australia; these countries must of necessity find alternative destruction technologies for their PCB-containing materials.

Another technology which is similar to incineration is represented by cement kilns used quite widely to destroy mainly liquid PCB-containing wastes. The PCB-containing liquids are introduced with the fuel in the cement kiln, thereby allowing the conventional fuel to be partially replaced by the liquid waste. This latter has often quite a high calorific value, and thus may be welcomed by cement kiln operators as representing a cheaper source of energy for their process. The operating conditions of cement kilns burning chlorinated wastes are typically subject to very close control by the appropriate authorities to ensure that levels of dioxin and furan which might be present in the off-gases are kept within the regulatory norms. The ability of these kilns to accept PCBs or any other chlorinated mixture is dependent to a considerable extent on the level of chlorine in the material, as more highly chlorinated materials present increasingly difficult complications.

In addition to these technologies, which allow high temperature destruction of chlorine-containing compounds, other processes exist and are operated in many countries. It is these other technologies allowing the destruction of PCBs without incineration which are the subject of this handbook.

7. PCB CONTAINING MATERIALS

The following materials and products, contaminated with PCBs are considered in this volume. The main characteristics of these different materials and products are described below, in order to allow a better understanding of the decontamination techniques which can be applied in each case.

7.1 Transformers

Transformers are important components of the process for generation and distribution of electricity. They allow the increase or decrease of the voltages at which electricity is transported and used. Power stations produce electricity at high voltages and it is more economic to transport electrical power over long distances at these high voltages. Closer to the place of use, the voltage must be decreased, for example to several thousand Volts for transport purposes, and to about 220 Volts for domestic uses. These changes are carried out by using transformers. Transformers can thus be widely seen in the countryside and in towns, in particular in countries where cost considerations mean that such equipment is placed above the ground instead of being buried in trenches, although it can be noted that an electrical transformer can vary in size from that of a very large room to being very much smaller than a matchbox.

A transformer is essentially a closed casing containing two sets of copper windings sharing a magnetic core. The relative number of copper wires in each winding determines the ratio of decrease (or increase) of voltage. Transformers are fitted with two connections to the outside, made up of the electrical conductor and the ceramic insulating protection.

The outer casing is made of iron or steel. The interior active parts consist of flat metallic plates serving as the magnet, surrounded by the windings. These windings are made up of copper wiring coated with a varnish or wrapped in insulating paper. In addition to these parts, a normal transformer contains (perhaps surprisingly) wooden struts holding the active parts in place; this of course is because wood is neutral from the electrical point of view. The whole of the free space is filled with an electrical oil, and it is this oil which has for very many years been based on PCBs. Today, only non-PCB-containing substitutes are used in new equipment.

The complete decontamination of a transformer presents problems, due to the structure of this equipment. Although metal surfaces such as casings can be easily de-contaminated with a solvent, two main problems arise in transformers:

First, the copper wires are coated with a varnish. This varnish has absorbed PCBs during its operational lifetime and these must be extracted; this process is much longer that than the time required to clean up the outer metal casing. It is thus advantageous to separate the components (casings, windings, etc.), and adjust the decontamination time to the characteristics of the component.

The second, more serious problem arises with the wooden struts and possibly paper present. These are very porous materials and very difficult to clean with a solvent. If not decontaminated to acceptable PCB levels allowing landfilling (which vary from country to country) these parts must be incinerated.

There are two ways to deal with the problem of transformer decontamination: The unit can either be removed from service, or the electrical oils can be replaced by a non-PCB substitute whilst the transformer is in operation. In the first case, complete decontamination leads to destruction of the transformer, with recovery of most metallic components.

The second case is called "retrofilling." This involves removing the electrical oil, even while the transformer is in service, and treating this oil in a closed circuit to destroy the PCBs it contains. Several technologies exist for carrying out this retrofilling.

A disadvantage of retrofilling is that the PCBs are present not only in the oil, but also in the transformer's porous wooden structure. The contained PCB will diffuse out only slowly from the wood while the concentration of the PCBs in the cleaned oils is being reduced by the decontamination process. This diffusion process is not completed during the time of the retrofilling operation, and the PCB content of the oil of a retrofilled transformer will later slowly increase with time, as further out-diffusion continues. If this increase leads to a higher PCB level in the new oil than that set by legislation, a subsequent retrofilling operation(s) will have to be carried out.

Despite these factors, retrofilling is often usefully applied to large transformers or those which are inaccessible for various reasons.

The technologies proposed for transformer decontamination must take all these factors into account.

7.2 Capacitors

Like a transformer, a capacitor is a sealed metal container containing an active core. In the case of a capacitor, this core is made of continuous sheets of a thin metal foil (aluminium) rolled together and separated by an insulating film of polypropylene and/or paper impregnated with PCBs. This core fills the casing of the capacitor but all free space is filled with an electrical PCB oil.

This structure is relatively difficult to decontaminate. Generally speaking, capacitors are destroyed by incineration after draining of any PCB oil which may be present, and separation of the casing from the core. It is not possible to easily remove the PCBs held in the interior of the foil winding.

Nevertheless, some technologies do exist for treating the capacitors so as to decontaminate them and recover the useful materials for recycling. In the case of capacitors, the useful materials are the outer casing and the aluminium foil making up the windings. This aluminium is of electrical quality and can command a high price as recycled material if completely decontaminated.

The main challenge in recycling this foil is to ensure that a good separation can be obtained between the aluminium and the paper/polymers sheets. It must be taken into account that these insulating films hold absorbed PCBs, and that any solution to recover the aluminium, which is fairly easy to decontaminate with a solvent, must also deal with this contaminated material. Some capacitors are treated and recycled even in countries where incineration is available; in these cases, the polluted organic film materials (difficult to decontaminate) can then be incinerated. This represents a good technically feasible and economic approach to capacitor decontamination with material recovery.

7.3 Transformer oils

A PCB-contaminated oil can be treated in two basic ways:

1. removal of the chlorine atoms from the PCB molecule and re-use of the oil ("dechlorination"); or,

2. destruction of the PCB oil by oxidation (incineration).

Dechlorination is generally carried out chemically by reaction with a reducing agent which removes the chlorine atoms and yields an oil which can be adapted for re-use.

Case (2) is a technique applied only by companies who remove PCB oils from transformers prior either to incineration of the transformer or to its dismantling to recover useful metal components.

7.4 Waste oils

This category of product is unfortunately common in industry; it includes various waste oils which are collected together for future disposal. It often happens that PCB-contaminated waste oils are inadvertently mixed with normally generated waste oils, which themselves do not present a particular hazard. The mixed oils are then found to be contaminated and must be treated by appropriate PCB destruction technologies.

A difference exists between transformer oils and waste oils from the decontamination point of view. The former, being constituted of well-defined hydrocarbons and chlorinated hydrocarbons, can be decontaminated by the chemical methods described below. Waste oils on the other hand can be treated only after an analysis of their composition. Generally speaking they will have to be filtered to remove foreign bodies, and in particular will have to be treated to remove water prior to the decontamination. Because of this problem, however, and the costs it occasions, most contaminated waste oils are destroyed in high temperature incinerators or cement kilns where these exist.

8. THE SPECIAL CASE OF CONTAMINATED SOILS

As already pointed out, it is not within the scope of this handbook to describe the technologies applicable to the decontamination of soils. Methods for doing this are numerous because they have to be developed for each particular type of soil. Of the three categories of soil clean-up technologies below, only solvent washing is covered by this report.

1. The bio-remediation of soils makes use of selected bacteria to break down the chlorinated (and other) hydrocarbons in a soil. The bacterial formulation is generally added to the soil *in situ*. The degradation reaction is slow and can take several weeks, if indeed it works at all.

2. Incineration is an expensive but efficient way of destroying organic pollutants present in soil. It can however present problems in the case of soils containing a high clay content, since a good dispersion of the clay must be obtained, a fairly long process.

3. Finally, the contaminating PCBs can be extracted by means of venting (passage of air to remove vapours) or by solvent washing. In the case of venting, the vapours removed are condensed, generally on an active charcoal. While these processes lead to a clean soil, they in fact only transfer the PCBs to another medium: charcoal or a solvent. These products must then be treated to destroy the PCBs. It is the solvent obtained from such processes, and therefore containing PCBs, which can be treated by some of the methods described below.

II. ANALYSIS OF AVAILABLE PCB DESTRUCTION TECHNOLOGIES

We present here the replies received to the questionnaire sent out by UNEP Chemicals to companies identified as operating PCB destruction facilities. Nearly two dozen detailed replies were received, and these have been summarised in the fiches presented at the end of this report.

These technologies utilise mainly physico-chemical and chemical methods of decontamination and destruction, and do not include incineration. Nevertheless it must be recognised that some PCB destruction facilities included in this analysis incorporate, or require, an incineration step, generally for the final destruction of the PCBs extracted from electrical equipment. There are two reasons for this:

1. Some incineration companies have a first treatment step for electrical equipment which involves solvent cleaning of the equipment (transformers and/or capacitors), with recovery of metals for recycling. Some difficult-to-decontaminate components such as organic materials are then incinerated. Such companies are included in this report.

2. When oils are treated to extract the PCBs using a solvent, the PCBs are concentrated by distillation and a PCB-rich product is obtained. Although technologies exist for eliminating these products chemically, suitably equipped companies can also incinerate them. Because of this, companies exploiting incineration combined with a physico-chemical destruction process are included in this report.

The following tables (tables 1, 2 and 3) list companies who operate these processes.

Table 1: PCB Destruction Technologies for OILS

	Name of company	Technique	Oils re-use
1	ABB	Not applicable	-
2	AMEC GeoMelt	Vitrification (but oils must be absorbed on support)	no
3	Aprochim	Solvent concentration + conversion to HCL	yes
4	Bilger	Sodium	yes
5	Cintec	Not applicable	-
6	Cleanaway	Incineration	no
7	Eco Logic	Hydrogenation	no
8	ELF Atochem	Special case: combustion to HCL	no
9	Fluidex	Sodium	yes
10	Grosvenor Power	Dechlorination	yes
11	Manitoba Hydro	Sodium	yes
12	S D Myers	Dechlorination	yes
13	Ontario Power	Sodium	yes
14	Orion	Not applicable	-
15	Papusha Rocket	High temperature thermo-chemical	no
16	Petrochimtekhnologii	Plasma	no
17	Powertech	Sodium	yes
18	Sanexen (DCR)	Sodium	yes
19	Safety-Kleen	Sodium	as fuel
20	Shanks	Incineration	no
21	Shinko Pantec	Sodium	yes
22	TASSCO	Sodium	yes
23	Tredi	Incineration	no

Table 2: PCB Destruction Technologies for TRANSFORMERS

	Name of company	Technique	Transformer reuse	Metal recovery
1	ABB	Solvent cleaning (also retrofilling)	yes	yes
2	AMEC GeoMelt	Vitrification	no	no
3	Aprochim	Solvent cleaning followed by combustion to HCL	no	yes
4	Bilger	Sodium reagent after grinding	no	no
5	Cintec	Solvent cleaning	no	yes
6	Cleanaway	Solvent cleaning plus incineration	no	yes
7	Eco Logic	High temperature hydrogenation	no	yes
8	ELF Atochem	Not applicable	-	-
9	Fluidex	Retrofilling	yes	no
10	Grosvenor Power	Retrofilling	yes	no
11	Manitoba Hydro	Retrofilling	yes	no
12	S D Myers	Solvent washing, also retrofilling	no	yes
13	Ontario Power	Solvent cleaning	no	yes
14	Orion	Solvent cleaning plus incineration	no	yes
15	Papusha Rocket	Not applicable	-	-
16	Petrochimtekhnologii	By plasma destruction	no	yes
17	Powertech	Not applicable	-	-
18	Sanexen (Decontaksolv)	Solvent washing	no	yes
19	Safety-Kleen	Solvent cleaning	no	yes
20	Shanks	Partial incineration with metal recovery	no	yes
21	Shinko Pantec	Solvent Cleaning retrofilling	no yes	yes no
22	TASSCO	Retrofilling	yes	no
23	Tredi	Solvent cleaning plus incineration, also retrofilling	yes	no

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Table 3: PCB Destruction Technologies for CAPACITORS

	Name of company	Technique
1	ABB	Dismantling, decontamination
2	AMEC Geomelt	Vitrification after shredding
3	Aprochim	Dismantling with treatment of casings and cores to recover aluminium
4	Bilger	Grinding to small pieces, sodium dechlorination
5	Cintec	Dismantling, with treatment of casings and cores to recover aluminium
6	Cleanaway	Shredding, incineration
7	Eco Logic	High temperature treatment with H_2
8	ELF Atochem	Not applicable
9	Fluidex	Not applicable
10	Grosvenor Power	Not applicable
11	Manitoba Hydro	Not applicable
12	S D Myers	Dismantling, with treatment of casings and cores to recover aluminium
13	Ontario Power	Dismantling, with treatment of casings and cores to recover aluminium
14	Orion	Dismantling: casings decontaminated, cores incinerated
15	Papusha Rocket	Not applicable
16	Petrochimtekhnologii	Not applicable
17	Powertech	Not applicable
18	Sanexen	Not applicable
19	Safety-Kleen	Dismantling, solvent washing
20	Shanks	Dismantling followed by roasting with metal recovery
21	Shinko Pantec	Dismantling with decontamination by solvent washing
22	TASSCO	Not applicable
23	Tredi	Incineration

A. Non-dedicated elimination technologies

Across the world, certain existing industrial equipment has been used to eliminate PCB contaminated materials, in particular waste oils. The most common example is that of cement manufacturing kilns. Fuels used for cement manufacture in kilns can usefully be combined with waste oils contaminated with PCBs, depending upon the chlorine content of the PCBs. The advantage is that the waste material contributes calorific value to the fuel, and is simultaneously destroyed. However, it is imperative that the incorporation of PCB oils to a cement kiln operation be accompanied by strict control of the gas scrubbing equipment, and thus of the possible dioxin and furan emissions.

Two other examples of the use of existing industrial equipment for the destruction of PCBs can be cited. Although believed to be used on only a limited scale, they are mentioned here because they represent valid, if non-conventional methods for PCB destruction:

1. Destruction of PCBs in the molten salts found at the base of black liquor recycling boilers in the pulp industry. Molten salts are known to de-chlorinate PCBs and good levels of decontamination can be obtained when the PCBs are introduced into this molten salt;

2. Injection of contaminated waste oils into blast furnaces. Here the combustion and oxidation conditions are favourable to PCB destruction, and in addition the basic oxides present in the furnace can react with the by-products, e.g., hydrochloric acid, to neutralise them.

Such PCB destruction technologies based on **non-dedicated technologies** are excluded from this report. It must be noted however, that if they are applied within the rules of sound waste management, they may represent an acceptable way of destroying PCBs.

B. Processes for decontaminating transformers

Presently-used technologies for decontaminating transformers can be placed into two main categories:

1. Draining of the PCB oil from the transformer, decontamination of this oil, and re-injection of the decontaminated product into the transformer for re-use. This is **retrofilling.**

Companies offering this technology include:

- ABB
- Bilger
- Grosvenor Power
- S D Myers
- Fluidex
- Manitoba Hydro
- Shinko Pantec
- TASSCO

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- o Tredi.

2. Extraction of the PCB oil, solvent washing of the transformer, followed by dismantling and further decontamination of the components to allow recycling of the metal components. Such technology is exploited by:

    - o ABB
    - o Aprochim
    - o Cintec
    - o S D Myers
    - o Ontario Power
    - o Sanexen
    - o Petrochimtekhnogii
    - o Safety-Kleen
    - o Shinko Pantec

The following companies are essentially operators of high temperature incinerators and can recover transformers by solvent washing for metal recovery; the wash solvents are then distilled to allow recovery of some of the solvents, while the remainder are incinerated:

- o Cleanaway
- o Tredi
- o Orion
- o Shanks

Two other technologies to be noted are:

3. **Eco Logic** operate an original process in which the transformers, after a pre-treatment, are treated with hydrogen at elevated temperatures. The transformers are not recovered as such.

4. **AMEC GeoMelt** process transformers by a solidification technology which leads to an inert, non-leachable solid product which can be landfilled.

In assessing the above technologies it is important to consider to what extent the treatment processes are complete, that is to say, that they do not generate small amounts of difficult-to-eliminate residues. Such residues may in particular be the porous materials such as the wood and paper. Few companies cited above as using solvent cleaning carry out a complete decontamination; they are thus obliged to have recourse to incineration to dispose of these residues. This means that the proposed technology will only be applicable in countries where access to suitable incineration facilities exists.

Identified companies which do not themselves incinerate the PCB residues recovered from the decontamination process are:

1. ABB: residues sent to the chemical industry

2. Aprochim: PCB concentrates sent to Atochem for conversion to hydrochloric acid.

Comments on transformers

As can be seen, the technologies presented cover a wide range of degree of treatment and recovery of transformer components, a factor which must be taken into account in comparing technologies. Decontamination is never completely applied to all components, and this means that a residue remains which must be incinerated. In the best case this will be just the porous parts (wood and paper) unless the solvent technique is applied for long process times, and a product finally obtained which may be sent for land-filling if the residual PCB levels are legally acceptable. In other words, the total cost of treatment, including the cost of final disposal of residues, must be taken into consideration.

C. Processes for decontaminating PCB oils

1. Dechlorination with sodium

The most common technology is based on the use of metallic sodium to dechlorinate the PCB molecules and yield an oil which can be re-used, whether in the transformer or in some other use. The technology presents the advantage over incineration, not only of lower costs, but also of allowing recovery of the oil for re-use.

Sodium is a reactive metal which is easily oxidised; it reacts violently with water to give hydrogen gas, creating a potential fire hazard. It has a strong affinity for certain elements, however, including chlorine. It is this property which is exploited in the metallic sodium decontamination technology: the sodium reacts with the chlorine atoms on the PCB molecules to give sodium chloride.

The introduction of metallic sodium into a PCB oil leads to a reaction whose rate is dependent on the metal-oil interface. The rate of reaction between the solid metal and the PCB-containing oils depends on the extent of this interface, in that the finer the metal particles, the faster will be the reaction. Sodium dispersions proposed today are extremely fine and resemble emulsions, having a high metal surface area. The dispersion is used at a temperature which is above that of the melting point of the sodium, i.e., 98°C. Being liquid, the metal surface can be renewed continuously. In this way a reasonable reaction rate can be achieved, thus decreasing the cost of the decontamination process.

Secondary reactions can occur when PCBs react with metallic sodium. During the dechlorination step, the intermediate chlorinated molecules can polymerise and lead to the formation of a solid (polymer) containing chlorine. This product can no longer be dechlorinated and settles out of the reaction as a solid. A "clean" process therefore either must avoid the formation of polymer (done in one or two technologies identified) or must take the formation of this solid into account and introduce a separation step to yield the pure re-usable oil.

There are several variants of this sodium technology, and full technical details are not always available. The use of sodium to dechlorinate PCBs has been known for a long time. It is only with more recent technologies related to the preparation of very fine dispersions of the metallic sodium, however, that use of this active metal has become economically possible, and also possible from the point of view of fire risk reduction. The recent fine sodium dispersions are in fact relatively stable compared to the lump sodium reagents used earlier.

Companies which operate processes for oil decontamination based on the use of sodium are:

- Bilger
- Fluidex
- Manitoba Hydro
- Ontario Power
- Powertech
- Safety-Kleen
- Sanexen
- Shinko Pantec
- TASSCO

2. *Plasma related technology*

Plasma technology can be used to convert many complex organic compounds into simpler, harmless molecules such as carbon dioxide, water and hydrochloric acid. The principle is to subject a stream of the material to be treated to a high-energy electrical discharge. Extremely high temperatures can be attained in the plasma arc. At such temperatures, chemical substances are rapidly dissociated. The conditions of the plasma, in particular the pressure and the residual atmosphere, if any, can be adapted to specific requirements.

The sophistication of the technology means that treatment costs can be relatively high and the technology is not in widespread use. Plasma technology is exploited by Petrochimtekhnologii.

Related technology uses a combined plasma-chemical approach in which "atomisation" at high temperature is followed by an oxidation to harmless by-products. This technology is exploited by Papusha Rocket Technology.

3. *Other processes*

1. **S D Myers** exploit dechlorination processes based on an undisclosed reagent.

2. **Grosvenor Power**, in their retrofilling process, pass the oil over a supported catalyst which dechlorinates the oil for re-injection into the transformer.

3. The **Eco Logic** technology mentioned above for transformers (high temperature hydrogenation) can also be applied to oils.

4. The vitrification of PCB oils, after absorption on a solid support, is carried out by **AMEC GeoMelt**.

Comments on oils

The information provided by companies who replied to the questionnaire is often incomplete as far as the acceptable starting level of PCB is concerned. The sodium technology uses an amount of reagent which is proportional to the initial PCB content of the oil. In addition, the time of reaction will also be dependent on this initial PCB level. This means that the cost of the decontamination can only be expressed in terms of the oil contamination level. This is not always taken into account in the costs advanced for sodium processes.

D. Processes for decontaminating capacitors

Capacitors are similar to transformers in that they are made up of an active core, held in a metallic casing. However, the active core is not copper windings, but instead consists of interleaved rolls of fine aluminium foil, separated by thin films of paper and/or plastic.

Present day methods of dealing with capacitors can be classified according to the amount of the product which is recycled. All the technologies drain off any liquid PCBs before treatment. A possible classification would be:

1. No recovery of components, with the capacitors being incinerated, with or without shredding.

2. The casing of the capacitor is removed, and decontaminated by solvent washing; this is a straightforward decontamination process since the part is non-porous. The core is incinerated.

3. It is possible to go one step further and treat the core after removal from the casing. This decontamination step usually involves shredding of the core, and treatment with a solvent. This allows the level of residual PCB to be reduced to values allowing the product to be sent to landfill.

4. The technology which allows the largest amount of recycling is similar to 3, above, but also treats the mixed aluminium/plastic/paper residue to separate out these components, which are solvent washed. The aluminium metal can then be re-used; the only component to be disposed of is the mixed paper/plastic shreds which can go to landfill.

The degree of decontamination, or rather the fraction of the capacitor which is actually fully decontaminated varies from company to company (see company fiches). Overall, however, it can be said that capacitors are little decontaminated today; the vast majority are sent for destruction in high temperature incinerators.

The following companies treat capacitors, but only the first four offer technologies allowing decontamination of the core with recovery of the aluminium:

- o Aprochim
- o Cintec

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- o Ontario Power
- o S D Myers
- o ABB
- o Cleanaway
- o Orion
- o Shanks
- o Shinko Pantec.

Comments on capacitors

As in the case of transformers, complete decontamination of capacitors is rarely achieved, and a dependence on available incineration technology remains for disposal of organic residues in particular. Here again, it is technically possible to attain complete decontamination, even of the porous organic parts, but this will add significantly to the cost of the overall process.

E. General overall comments

It is hoped that readers will find useful the brief descriptions given of available decontamination technologies. However, in order to choose make a choice between the most suitable one in a given national and technical context, care must be taken to consider both the investment costs and the subsequent operational costs. Additional costs related to by-product treatment include the disposal of non-decontaminated residues, and of waste effluents in particular. Such details can in a second stage be obtained only from the companies supplying the technology.

F. Conclusions

This report is based on a survey of a relatively small number of companies, albeit all those of which UNEP was aware at the time. Indeed, not all those surveyed returned the questionnaires, so the report cannot, and does not claim to identify all vendors currently offering non-incineration PCB destruction technologies.

The replies to the questionnaires nevertheless show trends in terms of the technologies which are most widely used, and therefore presumably those which are the most reliable in terms of efficiency and cost. Specifically:

1. Incineration, when available, is the most widely available and used technology for PCB destruction;

2. Because of the cost of incineration, however, and its non-availability in many countries, alternative technologies are widely used;

3. Such technologies have the advantage not only of lower cost, but also of being able to treat economically much lower volumes of waste material; this is a significant advantage in particular for those countries now having to face up to the problem of PCB waste elimination; and,

4. Although oil decontamination can be achieved with technologies allowing complete destruction of PCBs, the case of transformers and capacitors can present problems because of the presence of a small amount of porous, organic materials which are costly to treat to obtain complete decontamination.

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ANNEX 1

QUESTIONNAIRE

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UNEP

UNITED NATIONS
ENVIRONMENT PROGRAMME

PCB Treatment/Destruction Technologies Questionnaire

Item	
1.1	**Name of destruction technology** ....
1.2	**Type of technology (1-sentence description)** ....
1.3	**Applicability:** To electric oils To waste oils To electrical transformers To capacitors To retrofilling
1.4	**Description of the technology** ....

	.... please provide additional information as appropriate (documentation)

1.5	**State of development** i) Does the technology exist as an industrial unit? .... ii) How many units exist, and in what countries? ....
1.6	**Treatment capacities** i) What is the capacity of existing plants (in tonnes/year) .... ii) Can the technology be adapted to higher or lower capacities? ....
1.7	**Waste material supply** In what form must the materials to be decontaminated be presented: drums? .... other packaging? .... pretreated, in the case of transformers and capacitors? .... other constraints? ....
1.8	**Other contaminated materials** Although not within the scope of this survey, can other contaminated materials be treated by the technology: soils? ....

	sludges and waters? .... various contaminated objects such as clothing, packaging, wood, etc.? ....

1.9	**Treatment costs** What are the approximate unit treatment costs for the following, if Applicable: o transformer oils? .... o waste oils? .... o transformers? .... o capacitors? ....
1.10	**Applicability of the technology to the cited contaminated materials** Are there conditions in which the technology is particularly well suited in terms of material to be treated, or efficiency? .... Does the technology have any constraints or limitations in terms of applicability, cost, etc.? .... What are the major advantages of the technology as compared to other approaches? ....

1.11	**Environmental considerations** Does the technology require accessory treatment installations for gaseous, solid or liquid effluents? If so, please give details ....
1.12	Please add any further information or comments you may wish to supply ....
1.13	**Contact information** (address, fax number, e-mail, ….) ....

ANNEX 2

REPLIES FROM COMPANIES

ABB Service (Germany)

Name: ABB Service GmbH
Postfach 10 01 44
44001 Dortmund
Germany

fax:	+ 49 231 9982 202
tel:	+ 49 231 9982 200
e-mail:	Dirk.Neupert@de.abb.com
web site:	www.abb.de/pcb

Contact person: D Neupert

Technology: Decontamination of electrical equipment by rinsing, with recycling of solids

Application: To transformers, capacitors, and to retrofilling

Availability: One fixed unit in Germany, 3 mobile units

Capacities: n/a

Costs: Very variable according to the product, but between 0.80 and 2.50 euros/kg*

Description:

a) Transformers are emptied and treated with hot solvent. After drying, the equipment is dismantled. The outer casings are sent for smelting; the components are then further cleaned for recycling. Copper windings are partially decontaminated. Ceramic parts are used in road construction.

b) The extracted PCBs are concentrated, the solvent being recycled. The concentrate is sent to chemical companies for conversion to hydrochloric acid. Highly contaminated wood and paper is thermally treated.

c) The overall recovery from transformers is about 98%, with the residual PCB contamination being about 2 ppm.

d) Capacitors can be treated by the same disassembly technique.

* 1 Euro = US $0.89 as of August 2000

AMEC GeoMelt (Australia, United Kingdom, USA)

Name: AMEC GeoMelt – Worldwide

UK/EUROPE		**USA/CANADA**	
AMEC GeoMelt		AMEC Earth and Environmental	
11 The Boulevard		2952 George Washington Way	
Crawley		Richland	
West Sussex RH10 1UX		Washington 99352	
United Kingdom		United States of America	
Tel:	+44(0)1293-528755	Tel:	+1 509 375 0710
Fax:	+44(0)01293-584994	Fax:	+1 509 375 7721
e-mail:	don.fraser@amec.com	e-mail:	LETatGeosafe@aol.com
web site:	http://www.geomelt.com	web site:	http://www.geomelt.com

ASIA PACIFIC REGION
AMEC Environmental Asia Pacific
Level 1, 431-439 King William Street
Adelaide, South Australia 5000
Australia

Tel:	+61 8 84103133
Fax:	+61 8 84103122
e-mail:	dosborne@amec.com.au
web site:	http://www.geomelt.com

Contact person:

Don Fraser (UK/Europe)
Leo Thompson (USA/Canada)
David Osborne (Asia Pacific)

Technology: Vitrification of contaminated materials

Application: To PCB-contaminated soil, waste, oils, soils and equipment

Availability:

One in Australia
One in Japan
Two in USA

Capacities: Each unit can process 30 to 150 t/day

Costs:

Transformer oils:	US$ 5-10/ gallon
Waste oils:	US$ 5-10/ gallon
Contaminated soils	US$ 500 / ton

Description: The batch process vitrifies contaminated soils and wastes by application of an electrical current between electrodes. Since the basic reaction is a vitrification, it is necessary to have present a material, such as soil, which acts as the vitrifying medium. Wastes, debris and oils and equipment such as capacitors can be added to soil for treatment.

Batches can be processed either in the ground (in situ) or above ground in refractory-lined vessels.

The organic materials, such as PCB oils are destroyed by thermally induced pyrolysis and dechlorination reactions in the hot soils adjacent to the molten media.

The unit is fitted with off-gas treatment units including scrubbers, thermal oxidisers and activated charcoal. The US EPA has permitted the technology for broad use in the USA for PCBs.

Aprochim (Brazil, France, Spain)

Name: Aprochim
B.P. 13
53290 Grez-en-Bouère
France

fax:	+ 33 243 70 68 26
tel:	+ 33 243 09 14 50
e-mail:	contact@aprochim.com
web site:	http://www.aprochim-env.com/

Contact person: Ph Kieffer

Technology: Decontamination of equipment and oils using solvents

Application: To transformers, capacitors, electrical oils, waste oils, retrofilling

Availability: Three units: France, Spain and Brazil

Capacities: 15,000 t/y, 2,000 t/y, and 2,000 t/y

Costs:

Transformer oils:	0.229 to 0.840 euros/kg*
Waste oils:	0.145 to 0.640 euros/kg
Transformers:	0.950 to 1.60 euros/kg
Capacitors:	0.160 to 1.40 euros/kg

Description:

a) Transformers and capacitors are rinsed and dismantled, the casings being separated from the cores. Similar parts (casings, windings, capacitor cores, etc.) are treated in separate chambers with solvent vapour. The time of treatment is adjusted to the nature of the part (accessibility of the solvent).

b) The cleaned metallic components are recycled as scrap metal.

c) Oils are treated with the solvent to extract PCBs. The products are re-usable oils and also a PCB concentrate.

d) The solvent obtained from both equipment and oil decontamination is distilled continually for re-use, and the PCB

* *1 Euro = US $0.89 as of August 2000

concentrate converted to HCl at the ATOCHEM chemical plant, also in France.

e) The technology is also used for decontaminating soils, concrete, rubble, etc. It is available as a mobile unit.

Bilger (France, Germany, Netherlands, United Kingdom)

Name: Bilger Umweltconsulting GmbH
Rodenbacher Chaussee 6
63457 Hanau
Germany

fax:	+49 6181 58 2686
tel:	+49 6181 58 2684
e-mail:	310064528900-001@t-online.de
web site:	http://www.tp-hanau.de/bilger/index.htm

Contact person: E Bilger

Technology: Sodium for destruction of PCBs in transformer oils

Application: To electrical and waste oils; also to transformers and capacitors

Availability: Full-scale commercial plants in France, UK, Netherlands and Germany plus one half-scale plant in Germany.

Capacities: Between 3,000 and 50,000 t/y, according to the plant

Costs: Dependent on many factors; generally lower than the cost of incineration, except in the case of pure PCBs.

Description: The contaminated oils are treated with very fine metallic sodium particles (between 1 and 10μ diameter). The chlorinated organic molecules react to give non-chlorinated organic products plus sodium chloride.

The technology can also be applied to transformers and capacitors if these are previously ground up to fine pieces; this can be done by grinding in liquid nitrogen. The sodium dispersion used in the technology is available commercially.

Cintec (Canada)

Name: Cintec
7475 Newman Boulevard
Suite 309
LaSalle
Quebec
Canada H8N 1X3

fax:	+1 514 365 2964
tel:	+1 514 364 6860
e-mail:	pguerin@cintec.ca
web site:	http://www.cintec.ca/English/English.htm

Contact person: P Guerin

Technology: Solvent washing allowing recycling of metallic parts

Application: To electrical transformers and capacitors

Availability: Three units in Canada

Capacities: Capacity: 2,000 t/y

Costs:

Transformers:	Can$ 1.50 /lb*
Capacitors:	Can$ 4.00 /lb

Description: a) After drainage, the transformer is washed with solvent prior to dismantling. The core is then separated from the casing and placed in a decontamination unit which operates under reduced pressure. The parts are subjected to cyclic treatment in which solvent liquid and vapour alternate.

The cleaned parts are then separated into like metals and can be reprocessed as metals for a second fusion (e.g., copper coils), or can be recovered for re-use (metal armatures, screws, ferro-magnetic cores, casings, etc.).

b) The capacitors are first drained and then dismantled, the aluminium/paper coils being separated from the casings. These latter

* 1 Can$ = US $0.67 as of August 2000

are decontaminated with the transformer casings. The cores are cleaned with the same cycling solvent treatment.

The solvent is recycled and the concentrated PCB sent for incineration.

c) The porous materials (wood, cardboard) cannot be decontaminated satisfactorily, and are incinerated. Cintec also disposes of a small mobile incinerator.

d) Transformers and capacitors with over 10,000 ppm PCBs /kg, can be treated to reduce these levels to under 50 mg /kg in porous material, and to 0.010 mg/ 100 cm^2 on metallic surfaces.

Cleanaway (United Kingdom)

Name:	Cleanaway Airborne Close Arterial Road Leigh-on-Sea Essex SS9 4EL United Kingdom	
	fax:	+44 1277 723524
	tel:	+44 1277 234567
	e-mail:	mhall@cleanaway.co.uk
	web site:	http://www.gknplc.com/customers/industserv/cleanaway.htp

Contact person: Mervyn Hall

Technology: Solvent cleaning of transformers with metal recovery; and high temperature incineration of residues, oils and also chopped capacitors.

Application: To electrical transformers, capacitors, oils and all PCB contaminated materials.

Availability: One incinerator in the UK

Capacities: In excess of 5,000 t/y

Costs:

Transformer oils:	US$ 800 /t
Waste oils:	US$ 500 /t
Transformers:	US$ 1,000 /t
Capacitors:	US$ 1,600 /t

Description: Contaminated transformers are solvent cleaned and valuable metal fractions recovered. PCB residues are sent for destruction by high temperature incineration (above 1200°C).
Capacitors are shredded prior to high temperature incineration.

Organic residues from transformers are incinerated, together with any other secondary contaminated materials.

Eco Logic (Australia, Canada, Japan)

Name: Eco Logic
143 Dennis Street
Rockwood
Ontario
Canada NOB 2KO

fax: + 1 519 856 9235
tel: + 1 519 856 9591 ext. 203
e-mail: kummlib@eco-logic-intl.com
web site: www.eco-logic-intl.com

Contact person: Beth Kummling

Technology: High temperature reduction of organic compounds to methane and HCl in the presence of hydrogen at 850-875°C.

Application: To electrical oils, waste oils, electrical transformers, capacitors, and retrofilling

Availability: Full-scale commercial plant in Australia
Portable demonstration units in Canada and Japan

Capacities: Full-scale (Australia): 840 t/yr
Portable demonstration plants: 2 to 50 t/yr

Costs: Not available; in many cases lower than incineration

Description: a) The Eco Logic decontamination technology is a high temperature, but non-incinerative process which involves the gas-phase chemical reduction of organic compounds by hydrogen at temperatures of 850°C or greater. Organic compounds are reduced to methane, hydrogen chloride and small amounts of benzene and ethylene. The HCl is neutralised on cooling the gas. Steam is used in the process for heat transfer purposes, and this favours formation of carbon monoxide and dioxide.

b) The process is made up of several steps. In the first reactor the various products to be treated are rendered into a suitable form for processing. The gas-phase reaction occurs in the main reactor. The third step is the gas scrubbing system; the fourth one concerns the compression of the product gases and the storage unit.

c) In the case of solid contaminated wastes such as electrical equipment, these must first be opened or punched to give access. They are then treated in the first reactor to desorb the contaminants. It is these latter which pass into the main reactor. Contaminated liquids can be injected directly into the main reactor for conversion.

d) The Eco Logic process has been used mainly for treating electrical equipment and pesticides. The process is versatile and acts on all organic compounds present in the waste; it can thus be applied to complex hazardous organic materials. Tests are under way to adapt it to other solids such as soils.

ELF Atochem (France)

Name: ELF Atochem
Usine de St Auban
04600 Saint Auban
France

fax:	+ 33 492 33 78 17
tel:	+ 33 492 33 75 00
e-mail:	Pierre.Cattet@stau.elf-atochem.fr
web site:	http://www.atofina.com/groupe/gb/f_elf.cfm

Contact person: P Cattet

Technology: Thermal conversion of PCBs to hydrochloric acid

Application: To electrical and waste oils, and also to other chlorinated residues

Availability: The plant is situated in southern France, at St Auban

Capacity: 5,000 t/y

Costs: n/a

Description: The high temperature furnace is fitted with a quench column and 4 absorption units for the HCl. The by-product gases are scrubbed. This process is characterised by high efficiency and zero effluent production.

The plant works in close collaboration with the solvent decontamination process of Aprochim, also in France, and converts to HCl the PCB solvent concentrates received from that company.

Fluidex (Australia, South Africa)

Name: Fluidex Engineering (Pty) Ltd
PO Box 9004, Edleen 1625
6, Ossewa Street
Chloorkop Ext 19
South Africa

fax:	+ 27 11 393 4222/4
tel:	+ 27 11 393 1033
e-mail:	fluidex@fluidex.co.za
web site:	www.fluidex.co.za

Contact person: Caron Boone

Technology: Chemical dechlorination with sodium

Application: To electrical oils, also retrofilling

Availability: Two units in Australia; one unit in South Africa

Capacities: 550 litres/hr

Costs: Transformer oils: approximately US$ 0.15 / litre (at 100 ppm PCB content)

Description:

a) The oil is first drained from transformers and capacitors, and then treated with a sodium dispersion to destroy the PCBs, forming a basic salt. The reaction by-products are separated out and the oil recycled. The process can treat PCB contents of up to 1000 ppm.

b) It can be noted that the technology is associated with an oil purification system (using Fullers earth), allowing the transformer oil to be cleaned up also of the particles which inevitably accumulate in a transformer due to cellulosic materials present in the transformer. This oil can then be re-used as transformer oil.

Grosvenor Power (United Kingdom)

Name: Grosvenor Power Services Ltd.
Carrington Business Park
Carrington
Manchester
England M31 4DD

fax:	+ 44 161 776 4078
tel:	+ 44 161 776 1955
e-mail:	sales@grosvenorpower.dem.co.uk
web site:	-

Contact person: Charles Beck

Technology: "Polygon": catalytic dechlorination process for PCB contaminated oils

Application: To electrical oils, including retrofilling

Availability: Two units exist in the UK, one of which is mobile

Capacities: Total capacity: 6,600 t/y

Costs: Transformer oils: in the range of £500 to £1,000/t depending on composition*

Description: The oil is passed through a bed of a patented catalyst which removes the chlorine, rendering the oil harmless and ready for re-use. No gaseous or liquid effluents are produced, but the solid catalyst must be changed and disposed of at the end of its lifetime.

The process is particularly suitable for treating smaller amounts of oils in countries not having access to incineration facilities.

No accessory equipment is required, only access to an electrical supply to operate the pumps and heating system.

* 1 £ = US $1.45 as of August 2000

Manitoba Hydro (Canada, USA)

Name:	Manitoba Hydro 1840 Chevrier Boulevard Winnipeg Manitoba R3T 1Y6 Canada		
		fax:	+ 1 204 474 4756
		tel:	+ 1 204 474 4366
		e-mail:	nmelnychuk@hydro.mb.ca
		web site:	http://www.hydro.mb.ca

Contact person: Nancy Melnychuk

Technology: Reaction with metallic sodium

Application: To oils, including retrofilling

Availability: Five units in USA

Capacities: 12,600 t/y

Costs: Transformer oils: Can$ 4/gallon* (for unspecified PCB content)

Description: The process uses metallic sodium to chemically destroy PCBs to common salt and non-hazardous by-products. The oil is heated before being placed in the reactor. After the reaction, the product is centrifuged to separate out the waste materials. The process generates 45 mg of sodium chloride/hydroxide solution per litre of oil processed; the product is reused industrially as caustic solution. A filtration is necessary to separate the solidified polymer which is formed. This is disposed of in a landfill.

The process is particularly well suited to low vapour pressure liquids with less than 5% water content. No gaseous effluents are produced. The treated oil is reused in electrical appliances.

* 1 Can$ = US $0.67 as of August 2000

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S D Myers (Brazil, USA)

Name: S D Myers International
180 South Avenue
Tallmadge
Ohio 44278
USA

fax: +1 330 633 6458
tel: +1 330 630 7000 (ext. 3200)
e-mail: dana_myers@sdmyers.com
web site: http://www.sdmyers.com/

Contact person: Dana S Myers, or Pierre Lefebvre (sdm.lefebvre@videotron.ca)

Technology: Decontamination of electrical equipment

Application: To transformers and capacitors

Availability: Two units in the USA
One unit in Brazil

Capacities: 400 to 11,000 t/year

Costs: on request

Description: Transformers and capacitors are drained of their fluids and disassembled. The components are cleaned with a solvent, the solvent being distilled for re-use. The parts are cleaned to a level of under 10 µg PCB/100 cm^2 and commercialised. The PCB concentrates are sent away for destruction.

About 95% of a transformer can be recycled; the figure for capacitors is much lower at about 25%.

S D Myers (2) (Canada, Saudi Arabia, United Kingdom, USA)

Name:	Same as above
Contact person:	Dana S Myers, or Pierre Lefebvre (sdm.lefebvre@videotron.ca)
Technology:	PCB-Gone: dechlorination
Application:	To mineral oils, and retrofilling
Availability:	Two units in US One unit in Canada One unit in the United Kingdom One unit in Saudi Arabia
Capacities:	7,000 to 12,000 t/year
Costs:	on request
Description:	The process dechlorinates oils and also allows removal of degradation by-products such as acids and sludges.

Can be applied to energised transformers of all sizes, reducing their PCB level to less than 50 ppm.

Upper limit for treatment is about 10,000 ppm of PCB content; free water and solvents must be absent.

The company also operates two other dechlorination processes called PCBX and PCBD:

PCBX treats contaminated oils with up to 10,000 ppm PCB content and lowers this to less than 50 ppm; particularly adapted for retrofilling.

PCBD treats oils in a relatively cheap stationary dechlorinator, and reduces PCB levels from about 800 ppm to less than 2 ppm.

The PCBX technology is operated in 2 units in the USA. The PCBD technology is operated in 2 units in Australia and 1 in South Africa.

Ontario Power (Canada)

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Technology:
a) Low temperature mobile chemical destruction process
b) Low temperature solvent extraction PCB decontamination process

Application:
a) To electrical and waste oils
b) To electrical transformers and capacitors

Availability:
a) Two trailers
b) One fixed unit

Capacities:
a) 1,000 l/h for each trailer for low-level PCB levels: under 7,000 ppm PCBs. About 30 kg/h of nearly pure PCBs can be treated
b) 200 t/yr of solid material

Costs: Very dependent on conditions, but in any case lower than incineration, for both technologies

Description:
a) The process uses metallic sodium to chemically destroy PCBs in oils, leading to common salt and non-hazardous by-products. The reagent is a fine dispersion of sodium in a mineral oil. The contaminated oil is heated before being placed in the reactor. After the reaction, the product is centrifuged to separate out the waste materials. The process generates 45 mg of sodium chloride/hydroxide solution per litre of oil processed; the by-product is reused industrially as caustic solution. A filtration is necessary to separate the solidified polymer which is formed. This is disposed of in a landfill.

b) The process is particularly well suited to low vapour pressure liquids with less than 5% water content. No gaseous effluents are produced. The treated oil is reused in electrical appliances.

c) The performances of the process have been studied in some detail, with respect to residual PCB levels after treatment. This is of interest in countries where the residual PCB limits are particularly low.

In Canada, where the technology was developed, the following residual legal levels can be reached easily:

- in solids: 50 ppm/kg
- on surfaces: 10μg/100 cm^2

The Japanese proposed standard of 0.5 ppm/kg of solid can also be attained, even though the processing time is longer. **NB**: the proposed surface contamination level in Japan for PCBs is 0.1μg PCB/100 cm^2.

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Technology: Solvent treatment with recycling of metals and recovery of oils

Application: To transformers, capacitors and oils

Availability: One unit exists in the Netherlands

Capacities: 20,000 t/y

Costs:

Transformer oils:	1,250 euros /t*	(US$ 1.11 /kg)
Waste oils:	1,500 euros /t	(US$ 1.34 /kg)
Transformers:	1,500 euros /t	(US$ 1.34 /kg)
Capacitors:	1,900 euros /t	(US$ 1.69 /kg)

Description:

a) The process is based on solvent cleaning associated to an incinerator. After draining, the transformer is flushed with solvent and then dismantled. The metal parts (steel, copper and aluminium) are then cleaned with solvent and reused. About 5% of the transformer (porous components such as wood and cardboard) is incinerated.

b) The capacitors are cut open and drained. The metals and insulating materials are cleaned, but the metal foil/polymer product is incinerated. About 50% of the capacitor is recovered for re-use (as metal).

* 1 Euro = US $0.89 as of August 2000

c) The oil is treated with a solvent so as extract the PCBs. The solvent is distilled to give clean solvent for re-use and a PCB concentrate which is transformed into hydrochloric acid.

d) The Orion process allows about 95% overall recycling of the contaminated materials. The remaining products, including the PCBs, are destroyed in accordance with Dutch government regulations.

Papusha Rocket Technology (Russian Federation)

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Technology: High temperature chemical destruction

Application: PCB and waste oils; all organic pollutants

Availability: One unit operating in Russia

Capacities: One t/hour

Costs: Approximately US$ 1,500 /t (independent of PCB concentration)

Description: Process based on both thermal and chemical treatment. The product is heated very rapidly to around 3000°C, this "atomising" the organic molecules. Subsequently, and very rapidly again, the gas stream is cooled in the presence of oxygen to yield simple biatomic molecules (HCl, CO2, etc.) which can be easily neutralised.

The process, based on rocket engine technology can be situated between conventional incineration and plasma-chemical detoxification. It can treat both liquid and powdered substances. Destruction is said to be 99.9995%.

For a 1t/h unit, the size is about 4.5m x 1.8m x 1.5m.

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Technology: Solvent washing of electrical equipment, followed by plasma-chemical destruction of PCBs

Application: To electrical equipment and oils, also waste oils

Availability: One unit in Russia, a larger one in China but working on other pollutants

Capacities: One module can treat 50-60 kg/h

Costs: The costs are estimated to be, under Russian conditions, US$ 580/t for PCB containing materials.

In the case of electrical equipment, the cost of treatment of a transformer is US$ 175/t of extracted PCB.

Description: This is a two-step process with electrical equipment being first decontaminated by use of a solvent to remove PCBs; the solvent is used in both the liquid and the vapour form. The metallic components are recovered for re-use.

The originality of the process lies in the second step which is a chemical-plasma unit allowing destruction of the recovered PCBs and also of similar pollutants. In fact this step has two stages:

1) heating of the pollutants to produce a gaseous phase (at as high a temperature as possible, without leading to decomposition)

2) introduction of the gaseous product into the main plasma reactor; (very short residence time, very high temperatures)

This process is claimed to allow the use of a very small plasma chamber, reducing corrosion and maintenance problems; only steam, carbon dioxide and HCl are produced.

Powertech (Canada, Japan)

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Technology: Removal of chlorine from PCBs by a metallic sodium dispersion

Application: To electrical and waste oils; also to capacitors

Availability: One unit in Canada; 1 pilot plant in Japan

Capacities: 700 t/y in Canada

Costs: Transformer oils: Can$ 0.90 /kg * (unspecified PCB content)
Waste oils: Can$ 0.60 /kg

Description: The oil is treated with a sodium dispersion to destroy the PCBs giving sodium chloride. The sodium dispersion used is available commercially.

The process is carried out at low temperatures and produces no gaseous effluents. The oil is recycled.

The technology can also be applied to solid substrates.

* 1 Can$ = US $0.67 as of August 2000

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Technology: Solvent washing of equipment, and removal of chlorine from PCBs by metallic sodium (PPM process)

Application: To electrical transformers and other electrical equipment, and also oils

Availability: Three units existing in USA

Capacities: 16,000 t/y for electrical equipment;
40,000 t/y for oils

Costs:

Transformers:	US$ 0.75 /lb (US$ 1.65/kg)
Capacitors:	US$ 1.50 /lb (US$ 3.3/kg)
Oils:	US$ 1.00 /gallon (about 22¢/litre)
Waste oils:	depends on oil, about US$ 2.00/gallon (about 44¢/litre)

Description: After being drained, the transformers and other electrical equipment are decontaminated using solvent and then disassembled. The cores and coils are treated in the same way. The solvent is recycled and re-used.

More than 90% of the total weight of electrical equipment is recovered as metals, the remainder presumably going to landfill or incineration.

The PCB concentrates are then dechlorinated with metallic sodium, leading to the formation of a sodium salt and a polyphenol.

The process leads to a non-regulated oil product which can be used as a fuel oil.

The process is particularly suitable for oils of under 1500 ppm PCB content. The maximum approved level for treatment is 12,200 ppm.

Sanexen (Canada)

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Technology: Decontamination of electrical components by solvent extraction; called the DECONTAKSOLV ™ process
Oil dechlorination process (DCR)

Application: To electrical transformers, capacitors, etc., and scrap metals.
To electrical oils, and retrofilling

Availability: Two units in Canada

Capacities: For oils, generally about 1,000 l/ min, but possibility of reaching a maximum of 5,000 l / min.
For transformers, 2,000 t /yr for each unit

Costs:

Transformers:	Can$ 1.50 to $2.50 /kg*
Transformer oils:	Can$ 0.50 to $1.50 /kg depending on PCB concentration and impurities

Description:

a) The process can treat contaminated electrical equipment such as transformers, circuit breakers and electromagnets allowing recovery of the metal content.

b) The technology uses a solvent in a closed circuit to extract PCBs from the components. The efficiency of the decontamination is dependent on the phase changes which are applied to the solvent during the process. This allows in-depth

* 1 Can$ = US $0.67 as of August 2000

penetration of the solvent into the interstices of the components. The solvent containing PCBs is then treated by the DCR process.

c) The transformer cleaning process has been in use since 1985 and enables high recovery levels for the metallic components.

d) The oils are treated with a sodium-based reagent and can then be re-used in transformers. The process, which exists as a mobile unit, treats oils with PCB contents of under 5000 ppm. Above this concentration, the process becomes less cost-effective.

e) The prices given above do not include the cost of incinerating residual porous materials, such as wood and paper.

Shanks (United Kingdom)

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Technology: Thermal treatment of certain equipment parts prior to recovery of the metals; incineration of all other materials

Application: To electrical transformers; oils and capacitors are disposed of in a high temperature incinerator

Availability: One incinerator in the UK

Capacities: Total capacity of all materials incinerated: 30,000 t/y

Costs:

Transformer oils:	GB£ 600 /t*	(about \$ 0.95 /kg)
Transformers:	GB£ 650 /t	(about \$ 1.03 /kg)
Capacitors:	GB£ 550 /t	(about \$ 0.87 /kg)
Waste oils:	GB£ 400 /t	(about \$ 0.63 /kg)

Description: The technology involves prior treatment of electrical equipment before incineration. This prior treatment (roasting) allows decontamination of certain parts of the transformer (windings) and capacitors (cores), and recovery of the metal for re-use. The remaining parts are incinerated, as is the oil of the electrical equipment.

The technology is classified as recycling in the case of transformers.

* 1 GB£ = US \$1.45 as of August 2000

Shinko Pantec (Japan)

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Technology: Solvent decontamination of transformers and capacitors
Chemical reaction dechlorination of oils with sodium dispersion

Application: To electrical equipment and waste oils

Availability: One plant in Japan

Capacities: One tonne pure PCB/year

Costs: Dependent on concentrations and on impurities in the oil

Description: a) The transformers and capacitors are solvent treated, dismantled, and then again cleaned with solvent. The process must be more effective than similar processes operated outside Japan, because of stricter Japanese legislation.

b) The oils are treated in a reactor with a specially made sodium dispersion, plus a promoter, to obtain a high reaction rate. In the case of high concentrations of PCBs a "moderator" is added to avoid the formation of polymerisation products containing chlorine, formed from the chlorinated species.

c) These two technologies have been applied to attaining the strict Japanese norms for PCB decontamination. These stricter norms mean that technologies developed outside Japan must all be adapted to respect these norms. The standards concern not only residual levels of PCBs in solids, but also the residual levels on the surface of metallic transformer parts which have been decontaminated (a level of 0.1µg PCB/100 cm² of metal surface is proposed in Japan, but not yet enforced).

d) The Japanese regulations are also strict for the effluents generated by sodium processes, and the Shinko Pantec technology includes a liquid effluent bio-treatment unit to deal with such effluents and render them harmless.

e) The Shinko Pantec process is of interest to countries, like Japan, which do not use incineration facilities to dispose of chlorinated hazardous wastes. The PCB concentrates obtained from transformer and capacitor decontamination must in these cases be destroyed by chemical means, which is what the Shinko Pantec technology makes possible.

TASSCO (Canada)

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Technology: Removal of chlorine from PCBs by metallic sodium in mobile units

Application: To electrical oils, retrofilling

Availability: One unit in Canada

Capacities: n/a

Costs: Transformer oils: the cost depends on the specifications of the oil to be treated and the residual level to be attained.

Description: The PCBs are dechlorinated with formation of a sodium salt giving a clean oil with a residual PCB content of under 2 ppm PCB. The sodium reagent is prepared by TASSCO, and is supplied to their clients as a dispersion.

The mobile unit can be applied to both transformer oils in drums and to the retrofilling of transformers. In the latter case, the transformer oil is re-tested after 90 days to check on the new level of PCBs. It is in fact usual in retrofilling for PCB to diffuse out of the porous materials inside the transformer (wood in particular) and to lead to a small increase in the PCB content of the oil. If the result is a content of over 50 ppm the retrofilling procedure is repeated.

The limit of initial PCB content for the treatment of transformers is 15,000 ppm.

Tredi (Canada, France)

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Technology: Decontamination of equipment using a non-flammable solvent, with recovery of metals; also, decontamination of equipment with re-use. The technology is exploited in association with a high temperature incinerator.

Application: To transformers and possibly capacitors

Availability: Two units in France, one in Canada, one being commissioned in Taiwan; other projects underway. A decontamination unit consists of several reactors of different sizes.

Capacities: Capacity of French plants: 12,000 t/y and 2,000 t/y

Costs: Not available

Description: a) The transformers are emptied of their PCBs by aspiration, and the core elements separated from the casing. The transformers are then turned upside down and treated in autoclaves with a solvent such as perchlorethylene. The time of treatment varies according to the nature of the part, the windings requiring much longer treatment parts than solid metals.

The process involves periods of alternating temperature and pressure. The solvent is regenerated by distillation and re-used.

b) The clean metals are recycled. The PCB concentrate, in the solvent, is incinerated in a high temperature incinerator. HCl gas is recovered from the gas-cleaning system.